A Field Evaluation of the Use of Small Trail Tractors to Maintain and Construct OHV Trails on National Forests in California

prepared for

USDA-Forest Service, Pacific Southwest Region

by

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Introduction

The use of mechanized equipment to maintain and construct Forest Service OHV trails has recently been questioned. Concerned citizens and representatives of OHV groups have claimed that mechanized equipment causes damage to trails and that equipment is being used inappropriately. Of particular concern is the use of small trail tractors.

To address this problem, the Pacific Southwest Region of the Forest Service awarded a contract to develop standards and guidelines that could be used to regulate the use of mechanized equipment on National Forest trails in California.

Letters from concerned citizens were reviewed, and existing Forest Service standards were evaluated. During May and June, 2001, equipment operators and OHV managers on twelve Ranger Districts were interviewed.

This report contains the results of this work. Included are findings and recommendations, a set of standards and guidelines, and a monitoring plan. The work was done under Natural Resources Professional Services Contract 53-91S8-NRM-08. Natural Resources Management Corporation, Eureka, California, was the prime contractor.

Objective

The objective of this field evaluation was to develop standards and guidelines and a monitoring plan for the use of mechanized equipment during the construction, reconstruction, and maintenance of OHV trails on National Forests in California. The purpose of the standards and guidelines is to prevent accelerated erosion, trail widening, and cumulative impacts from trail work with a trail tractor or mini-excavator. The monitoring plan will be used to evaluate the implementation and effectiveness of the standards and guidelines.

Methods

Issues were identified by reviewing letters from individuals and interest groups with concerns about how mechanical equipment is being used to maintain Forest Service OHV trails.

A review was also made of National Forest responses to the Regional Forester's request for written guidelines on the use of mechanized equipment in trail construction and maintenance. Reference material included existing Forest Service standards and guidelines and approved BMPs related to OHV trail construction and maintenance.

The primary source of information for the study was a series of on-site interviews with Forest Service equipment operators and OHV managers. Between April 11 and June 14, 2001, approximately 11 days were spent in the field interviewing 17 equipment operators and OHV managers on 12 Ranger Districts on 8 National Forests in California. The trails visited are listed in Appendix 2, the personnel who were interviewed or provided comments by letter are listed in Appendix 3, and the equipment observed is listed in Appendix 4.

All but one of the interviews took place in the field, and most of them included observations of equipment in operation. Where we visited trails with no equipment in operation, we had detailed discussions on the type of equipment used to construct and/or maintain the trail, how long it had been since the last maintenance, how heavily the trail was used, and the type of OHV typically used on the trail.

The focus of the field interviews was on observing equipment in operation, interviewing equipment operators, and evaluating water control structures. Nearly all the trails we visited had been maintained or constructed with either a SWECO-type trail tractor or a mini-excavator. Most of the trails we observed were used primarily by motorcycles, but we also observed trails where the primary use was ATV, 4WD, mountain bike, or equestrian.

Issues Related to the Use of Mechanical Equipment for Maintenance and Construction of OHV Trails

The following summary of issues is based on a review of letters from concerned citizens and from an interview with Don Fuller, State OHMVR Division. Authors of letters are listed in Appendix 3.

LOSS OF TRAIL TREAD

Letter writers claim that trail tractors commonly blade soil off trails and onto adjacent natural slopes, and create berms that channel runoff and accelerate erosion. They claim that constant grading and grooming of trails, combined with OHV use, results in a constant loss of tread until bedrock or some other hard layer is reached. Those critical of the use of trail tractors also claim that trail grooming and the tracks of tractor cleats leave soil in a disturbed, loosened condition that is readily eroded. Some believe that once soil has been disturbed, it can never be returned to its natural stability and will eventually erode. Others believe the only way to control erosion on OHV trails is by hardening or paving. Some assert that water breaks create a trail which requires maintenance, and that outsloping is adequate to prevent erosion on OHV trails.

TRAIL WIDENING

Trail widening is a major issue with those critical of the use of trail tractors. Some believe that with every pass of a trail tractor soil is removed from the cut slope and bladed off the trail, making the trail wider with each pass. Some feel that any trail maintained by a trail tractor should be considered an ATV trail.

Some who provided comments also claim that widening of trails could be considered growth inducing, i.e., wider, smoother trails encourage more use.

SINGLE-TRACK CHARACTER

Some concerned citizens believe trail tractors should not be used to maintain OHV trails because this converts single-track trails to ATV trails. They also claim that regular maintenance with trail tractors does not allow trails to develop a single-track character.

MAINTENANCE

Those who object to the use of trail tractors claim that a properly designed trail should not require regular maintenance by mechanical equipment. They also claim that trail tractors are used to blade the tread on entire trail segments, when maintenance is often only needed on a small portion of the trail.

SOIL MOISTURE

There is a narrow window of time when soil moisture conditions are suitable for soil compaction. Some of the letter writers claim that trail tractors are being operated outside this window of favorable soil moisture, displacing dry soil and causing more damage than would have occurred had the trail been left untreated.

ACCOUNTABILITY

Some critics of SWECO-type trail machines believe machine operators and their supervisors should be held accountable when these machines are used inappropriately.

NEPA PROCESS

The Forest Service position is that the use of trail tractors such as the SWECO is adequately covered by a categorical exclusion. Those critical of the use of SWECO-type trail tractors claim that such use is subject to a full NEPA review through an EIS.

Background

One of the primary goals of OHV trail management is to design, construct and maintain trails to minimize tread loss and sustain long-term use. When water is allowed to concentrate, its erosive power greatly increases. Specific water control structures are designed to collect and disperse runoff water before it can concentrate. Basic water control structures include insloping with an inside ditch and cross drains, outsloping, rolling or reversing the grade, rolling dips, lead-off ditches, and waterbars. These structures are often used in combination to provide effective drainage.

The terminology associated with water control structures can be confusing. The terms water control structure and drainage structure are the most generic and include all structures designed to control, collect, transport, or disperse water. The term waterbreak includes those structures designed to intercept the flow of water down roads or trails and disperse it before it can concentrate. Waterbreaks include such structures as waterbars, rolling dips, lead-off ditches, open top culverts, and reverse grade rolling dips (see Appendix 1, Photo 8), all of which have specific design specifications.

Insloping is rarely appropriate for OHV trails; traditional waterbars, such as those used on seasonal roads and skid roads, are designed for occasional 4WD traffic or for no traffic at all, and do not hold up under OHV traffic. Outsloping, with or without rolling dips, can be very effective in draining seasonal roads, but OHV traffic on most single-track trails creates an outside berm that renders outsloping ineffective. A rolling dip, especially if created by reversing the grade during trail layout, is one of the few water control structures that can hold up under heavy OHV use. The standard rolling dip used on roads is designed to accommodate truck traffic, and is not

suitable for OHV trails. Other types of water control structures generally do not hold up under OHV use.

Many OHV trails were not initially designed or located for OHV traffic. Retrofitting these trails with reverse grade rolling dips is very difficult. Over the years, OHV managers and equipment operators have developed a rolling dip design that can withstand heavy OHV traffic. When properly constructed, these "OHV rolling dips" can withstand heavy OHV traffic for 3 to 5 years, or even longer, before maintenance with mechanical equipment is needed. Construction of these OHV rolling dips, however, requires moving a substantial amount of soil, and construction and maintenance must take place when the soil is moist to achieve adequate compaction (see Appendix 8). A SWECO-type trail tractor and a considerable amount of operator skill are required to construct and maintain these OHV rolling dips.

The "OHV rolling dip" developed specifically for OHV trails is quite different in design from a standard rolling dip. It also does much more than just divert water. The catchment basin at the drainage outlet, incorporated into the design of an "OHV rolling dip" where appropriate, allows soil eroded from the trail to be collected and put back onto the trail tread or onto the OHV rolling dip structure itself.

Findings

The following findings summarize the most significant observations we made during our field interviews. These findings provide the basis for the Standards and Guidelines that follow.

Not all of these findings apply to all the Districts we visited. OHV Management programs vary widely from Forest to Forest within the Region, and in some cases even vary significantly among Ranger Districts within a National Forest. There are many reasons for this; proximity to urban areas, history of OHV use, differences in topography, elevation, climate, and soil type are just a few. However, at least part of the variability is due to differences in management emphasis on Forests and Districts, and to a lack of Regional emphasis, direction, and coordination.

Some of these findings are not directly related to the issue of trail maintenance with mechanical equipment. However, these findings are all interrelated, all affect District OHV programs, and ultimately all affect how OHV trails are maintained.

1. Forest Service personnel management has a major effect on how mechanized equipment is used in trail maintenance and construction.

It takes time to become an effective trail tractor or mini-excavator operator. Many skills besides operating the equipment are involved; a knowledge of basic erosion control processes and of how the flow of OHV traffic affects drainage structures are two examples. Gaining these skills may require years of experience on trail systems in a specific geographic area. Some Ranger Districts need to do a better job of retaining skilled operators and OHV managers by providing training, competitive salaries, opportunities for advancement, and a career path.

A knowledge of local conditions appears important. Some of the best OHV programs we observed were on Districts where OHV managers had been in place for 20 years or more. The quality of OHV programs also appears higher where a core staff does the complete job of OHV management, including law enforcement, signing, and rider contacts, as well as construction and maintenance.

2. Equipment operators, not the equipment, are the key to effective OHV trail maintenance and construction with mechanical equipment.

After observing several operators, we began to see very clearly that it was the operator, not the equipment, that made the difference between doing a good job and creating a problem when using SWECO-type trail tractors and mini-excavators. We observed operators with several years of experience on SWECO trail tractors who still did not seem to understand what was needed to achieve good trail drainage. Improper construction of OHV rolling dips and moving more soil than necessary were the most common problems observed.

There are several excellent operators and OHV programs in the Region, but there are also Districts that need a lot of help. Ways are needed to share the knowledge and experience of the better operators. Unfortunately, Districts with experienced operators and good programs have no incentive to share their knowledge—they are too busy maintaining and improving their own OHV programs—and the Districts that need help are often not even aware that their programs are not up to standard.

3. ATV use, not maintenance by SWECO-type trail tractors, is the primary cause of trail widening.

On the trails we observed and rode, the primary cause of trail widening appears to be ATV traffic, not maintenance with SWECO-type trail tractors. We observed numerous single-track trails constructed and/or maintained with SWECO-type trail tractors (see Appendix 1, Photos 6, 7, 8, 9).

The single-track character of OHV trails preferred by many motorcycle riders cannot be maintained under mixed motorcycle and ATV use. Several OHV managers are aware of this problem and use various strategies to restrict ATV use on single-track trails. One approach is keeping the trail segment at the trailhead too narrow for ATVs; another approach is installing ATV barriers at trailheads (see Appendix 1, Photo 10). It appeared to us that more information is needed on ATV rider preferences and behavior so opportunities for ATVs can be provided that do not conflict with other trail uses.

Although various combinations of trail use do work in some places, it appeared to us that off-site impacts and loss of trail tread can be minimized most effectively when trails are designed and maintained for one specific type of use.

4. Proper drainage is critical to preserving tread and minimizing off-site impacts to water quality, and this drainage cannot be provided on many OHV trails without mechanized equipment.

Properly constructed OHV trail rolling dips are too large to be constructed by hand. The volume of soil involved and the distance it must be moved is too great. Good soil compaction is essential if OHV rolling dips are to last 3 to 5 years before maintenance is needed. Small lifts of moist soil, compacted by trail tractors, are essential to obtaining adequate compaction during construction and maintenance of OHV rolling dips (see Appendix 8).

It should be noted that not all trails require OHV rolling dips for drainage. On some Districts, OHV trails are drained using outsloping and reverse grade rolling dips, and are maintained by hand or with mini-excavators. The type of drainage appropriate for a specific OHV trail will vary with trail design, soil type, season of use, type of use, and amount of use.

5. Properly constructed OHV trails can sustain up to three to five years of use before they need maintenance with mechanical equipment.

When properly located, designed, and drained, even heavily used OHV trails can withstand three to five years of use before maintenance is needed. We observed several heavily used trails that had not been maintained for five years and were in need of only minor maintenance such as reclaiming sediment from rolling dip outlets and touching up the OHV rolling dips.

The need for maintenance varies considerably with trail gradient, soil type, and amount and type of use. Some trails will require annual maintenance. However, we did observe one single-track trail, constructed with a SWECO trail tractor and drained by outsloping and reverse grade rolling dips, that probably can be maintained indefinitely by hand; this trail gets heavy use, but 80% of the use is by mountain bikes. We observed OHV trails on very fine sands derived from granitics that require annual maintenance with a mini-excavator (see Appendix 1, Photos 3 and 4).

Trail gradient strongly affects the need for maintenance. Keeping trail gradients low was a high priority for several OHV managers we interviewed. One OHV manager tried to keep average gradients around 6%, with occasional pitches of 8 to 10%. Other OHV managers tried to keep gradients around 8 to 12%, with steeper pitches less than 20 feet long where possible. Trails with steeper gradients are necessary for a variety of reasons, but they do require special treatment such as hardening, and a higher level of maintenance.

6. The period of time when soil moisture is sufficient to obtain soil compaction is limited. The availability of equipment and operators during this window limits the amount of trail that can be maintained in a season.

In most areas where OHV rolling dips are required, the period of time when soils are sufficiently moist is limited to several weeks. Experienced operators, and equipment in good repair, must be available during this narrow window. Some Districts have old equipment that is frequently down for repairs. This is a major problem if breakdowns occur during the critical moisture period when every day counts.

Sharing equipment among Ranger Districts is often not effective. Where Districts must operate in the same window of favorable moisture, additional equipment is needed to keep up with maintenance. But purchasing new equipment will not always solve this problem. Hiring and training equipment operators is often a greater limitation.

Where soils are too dry to compact, some Districts have tried watering down OHV rolling dips in an attempt to extend the operating season. There may be unique circumstances where this solves a specific short-term problem, but watering is not an acceptable substitute for naturally moist soils. Adequate compaction can only be obtained when suitably moist soil is compacted in small lifts by heavy equipment (see Appendix 8). Applying water to structures already constructed in dry soil will not result in adequate compaction.

It should be noted that mechanized equipment can still be used for some operations when soils are dry. New trails can be constructed under dry soil conditions, provided the drainage structures are reverse grade rolling dips, not OHV rolling dips, and that the trails remain closed to all use for a season. Rehabilitation work on closed trails can also be done with mechanized equipment when soils are dry.

7. There are no written design specifications for OHV Rolling Dips.

Even though they are one of the most important drainage structures used to drain OHV trails, and are commonly used, there are no standard design specifications for OHV rolling dips. The knowledge needed to construct and maintain these structures exists only in the collective memory of a handful of experienced equipment operators. Their knowledge and experience needs to be captured in drawings and written instructions for the benefit of less experienced equipment operators.

8. Many OHV trails were not originally designed for OHV use.

Many OHV trails were originally old logging or mining roads, logging skid trails, fuel breaks, foot trails, or horse trails. Some trails were user located. Because of this history, OHV trails often have an alignment that is less than ideal for good drainage. Trails that were originally roads or skid trails often have wide treads, which may appear narrower over time as vegetation encroaches.

Most Districts have a backlog of trails that need realignment or replacement because they cannot be effectively drained and maintained. Over time, these trails are being replaced with properly designed trails. But even with new trails, the best alignment for drainage is not always possible. Sensitive plants, spotted owl areas, archeology sites, and other land management issues often force OHV managers to accept alignments and drainage that are less than ideal.

9. Immediately after mechanical maintenance, many single-track OHV trails appear to have become wider, but their single-track appearance returns over time.

OHV traffic on single-track trails causes a berm to build up on the downhill side of the trail. During trail maintenance (with either a SWECO-type tractor or a mini-excavator) this berm may be pulled back onto the tread (see Appendix 1, Photo 1). Brush clearing may accompany this operation. This can give the appearance that the trail has been widened even though there has been no actual change in trail width. These trails often return to their single-track appearance within a few months as needles and leaves accumulate, and as OHV traffic defines a new tread.

It should be noted that not all berms are routinely pulled back onto the tread during maintenance. Some berms are left in place for safety reasons, on turns, or to channel runoff intentionally. In some soils the berms contain a large amount of rocks that were intentionally removed from the tread.

10. Monitoring of OHV trail maintenance is inadequate.

The monitoring we observed is generally disorganized, anecdotal, and in most cases undocumented. A notable exception is the monitoring done on the Cannell Meadows Ranger District of the Sequoia National Forest. For over 20 years this District has monitored trail segments randomly selected from their whole trail system. They have photos and notes for each monitored segment, and photo points are permanently monumented in the field with metal tags. This monitoring program could serve as a model for other Districts.

Most other Districts have varying levels of monitoring that include before-and-after photos, photo points at critical sites, and some notes. There are a few cases where information has been

collected that could be used to document long term trends. However, most monitoring is not well organized.

Monitoring designed specifically to evaluate the impacts of mechanized equipment on trail maintenance is totally lacking.

11. Forest Specialists are generally not involved in OHV programs and sometimes give contradictory recommendations.

With very few exceptions, we observed a lack of involvement in OHV programs by Forest specialists such as soil scientists and hydrologists. Some operators complained that even when specialists were involved, their recommendations were contradictory and conflicting.

12. Changes in technology and use patterns are creating challenges for OHV managers.

Motorcycles have become more powerful over the years and now have sophisticated suspension systems. Rough sections of trail no longer slow them down, and their tires grip trail treads more aggressively. Modern suspension systems on mountain bikes also allow bikers to ride at higher speeds, causing increased tread wear when they brake. There has also been a dramatic increase in trail use by ATVs in recent years.

The recent strong economy has contributed to these changes. Greater numbers of riders can now afford to travel greater distances and use trails that were previously used lightly. Riders are buying larger, more powerful motorcycles and ATVs. At the same time, the strong economy has made it more difficult to hire and retain qualified equipment operators.

The result of this changing technology and increased use is the need for more maintenance, more reconstruction and rerouting of trails, and the construction of larger and more durable OHV rolling dips. The more experienced equipment operators and OHV managers we observed were constant-ly looking for new equipment, adapting and modifying existing equipment, and developing trail management techniques to keep up with changes in OHV technology and use patterns.

13. The Districts with the largest and best managed OHV programs appear to be getting the most funding, while Districts with serious maintenance needs appear to be getting less than they need.

We are not sure of the cause of this problem, but management emphasis and leadership at both the District and Forest levels are probably major factors. On the less well-funded Districts, OHV managers spend a large portion of their time writing grant proposals at the expense of on-the-ground work. For whatever reasons, the most skilled equipment operators appear to be located on the Districts with the biggest OHV programs.

Standards and Guidelines

The following Standards and Guidelines were developed after observing the practices and techniques used by equipment operators, experienced as well as less experienced. They are not all-inclusive, but they do address the issues raised by those critical of the use of mechanized

equipment. Good operators should have no problem meeting these standards; they are already meeting most, if not all, of them.

1. Use certified operators, or persons under their direct supervision, to operate trail tractors and mini-excavators.
2. Construct new trails using R-5 design standards.
3. Close newly constructed trails to all use for one season.
4. Construct OHV rolling dips using design standards (standards to be developed; see Finding 7 and Recommendation 3).
5. Before moving equipment in, examine trails to determine the need for maintenance with mechanical equipment.
6. Lift the blade and walk equipment across sections of trail that need no maintenance.
7. Examine drainage structures, and the tread between them, for evidence of tread loss before starting maintenance.
8. At failed drainage structures, determine the cause of failure before starting repairs.
9. Recycle soil collected in rolling dip outlets into rolling dip structures or back into the trail tread.
10. Do not blade outside berms off the trail as sidecast; work berms back into the trail tread.
11. Repair rills and gullies in treads with soil reclaimed from rolling dip outlets or from outside berms, not with soil bladed from the trail tread.
12. Blade soil sloughed from cutbanks, or from sideslopes above trails, only as needed to maintain a safe trail; do not undercut or blade into cutbanks.
13. Repair "stutterbumps" by ripping, blading, and compacting the trail tread when soil is moist (except for non-cohesive soils).
14. Move the smallest amount of soil necessary to meet the maintenance objective.
15. Defer maintenance on drainage structures, or do hand maintenance, where soil is too dry or too wet for compaction.

Monitoring

The Standards and Guidelines should be monitored to assure they are being implemented and that they are effective in maintaining trail tread and minimizing off-site effects on water quality.

The monitoring discussed here and in Appendixes 5, 6, and 7 deals only with the issues raised concerning the use of mechanized equipment in trail maintenance and construction. In future years, this monitoring may be incorporated into a more comprehensive, Region-wide trail monitoring program.

OPERATOR SELF-EVALUATION

Monitoring occurs at many levels. One of the most important functions of monitoring is to provide feedback to equipment operators on how well they are meeting standards. For this reason, the Standards and Guidelines have been put into the form of a checklist (Appendix 6)

that equipment operators are to fill out before and after trail maintenance and construction. The checklist serves two purposes. First, it gives the operators a quick review of the Standards and Guidelines before starting a new job; second, it gives them an opportunity for self-evaluation after completing a job. We suggest the checklist be completed for all trails maintained or constructed with mechanical equipment.

COMPLIANCE MONITORING

Compliance monitoring is simply checking to see that a field checklist was filled out on all trails maintained or constructed with mechanical equipment. During the first year, this monitoring should be done on each District that has maintained or constructed trails with mechanical equipment.

IMPLEMENTATION AND EFFECTIVENESS MONITORING

Implementation monitoring should be done to determine whether the Standards and Guidelines were followed. Effectiveness monitoring should be done to determine whether the use of the Standards and Guidelines minimized tread loss and sedimentation. For one or two years, implementation and effectiveness monitoring should be done on each District that has maintained or constructed OHV trails with mechanized equipment.

To eliminate bias in sample selection, implementation and effectiveness monitoring should be conducted on randomly selected OHV trail segments. Initially, this monitoring should be conducted by earth science professionals such as soil scientists, hydrologists, or geologists who have erosion and sediment control experience and are familiar with OHV trail design and use. In future years, other people trained by erosion control specialists could conduct the monitoring.

Appendix 5 is a monitoring plan that describes how to sample for compliance, implementation, and effectiveness monitoring. Appendix 7 is a form for implementation and effectiveness monitoring. The monitoring plan and forms recommended should be considered first approximations that need field-testing before they are adopted.

Although the primary purpose of the monitoring we recommend is to determine whether the Standards and Guidelines are being implemented and are effective, a secondary purpose is to determine the extent of the problem of OHV trail construction and maintenance with mechanized equipment. All we can conclude from our brief survey is that this is not a problem on several of the Districts we visited and—with trained operators—it does not have to be a problem. No doubt there are places in the Region where the inappropriate use of trail tractors has caused the trail damage cited in the letters from concerned citizens. But without observations made on an unbiased sample of trails we have no way of knowing whether these are isolated cases or are more widespread. The implementation and effectiveness monitoring we propose would provide an objective evaluation of how widespread this problem is and where it occurs.

Recommendations

1. Forests and Districts should review their personnel policies as they relate to equipment operators.

Some Forests and Districts are doing a good job of retaining experienced equipment operators and OHV managers, but many are not. Personnel policies should be reviewed, and where necessary changed, to be sure all that is possible is being done to retain skilled equipment operators. The need for stable funding is closely related (see Recommendation 9).

2. The Region should provide more training for equipment operators.

We recommend more operator training. In addition to training on basic equipment operation, there is a need for advanced classes including training on basic principles of erosion and sedimentation, soil compaction, and trail design.

Most of the skills involved are best learned in a hands-on setting and through experience. Equipment operators need a development plan that includes a mentoring program, details to other Districts to work with experienced operators, technical reviews, and coaching.

An operator certification program should be developed for equipment operators and OHV managers. The program could be set up to allow temporary or conditional certification until a performance-based on-site examination has been passed. Operators with a conditional certification would require mentoring and a higher level of inspection. Highly skilled, experienced operators could be grandfathered in and could serve as mentors and inspectors.

3. Develop specifications for the OHV Rolling Dip and incorporate it into R-5 trail standards.

Design standards need to be developed and incorporated into R-5 trail standards, including specifications for shape, upslope and downslope transitions, moisture content, and techniques for compaction. Techniques for maintaining OHV rolling dips, including recycling soil collected in sediment basins, also need to be incorporated into R-5 trail standards.

4. Place a greater emphasis on completing as much maintenance as possible during the window of suitable soil moisture.

Timely funding, a sufficient amount of equipment, and skilled operators are essential during this critical time period. However, other options, such the use of contractors, should also be considered. Authorizing overtime during the window of critical soil moisture is another alternative, and it might prove to be more cost effective than trying to increase the number of machines and operators.

Watering dry soils should not be used as a strategy to extend the operating period. If used at all, watering should be used in very special situations with careful attention to bringing all the soil up to suitable moisture content before it is moved, and then compacting it in small lifts.

Soil moisture content is not an issue on some Districts in the High Sierra that have sandy granitic soils and where trails must be maintained during the dry season. Soil compaction is difficult to achieve under these conditions.

5. Implement and monitor the Standards and Guidelines included in this report.

OHV rolling dips cannot be constructed and maintained without the use of mechanized equipment. The Standards and Guidelines included in this report address the concerns raised by those who object to the use of trail tractors in constructing and maintaining trails. The monitoring we propose will test the effectiveness of the Standards and Guidelines, provide an objective assessment of the magnitude of the problem, and provide a means to check on compliance.

6. Provide more technical oversight and review of OHV trail maintenance and construction.

Review and inspection of trail maintenance by a qualified erosion control specialist would provide an additional way to share the knowledge of experienced operators and OHV managers, identify Districts in need of assistance, and provide additional one-on-one training. Technical inspections would also give equipment operators the opportunity to have their work critically reviewed from the perspective of soil loss, tread wear, and off-site impacts.

Forest soil scientists and hydrologists could participate in the technical reviews. This would give them a better understanding of the technical issues related to OHV trail maintenance and construction (see Finding 11). Exit reviews, if included, could provide feedback to line officers on how well their OHV program was meeting soil and watershed objectives.

7. Analyze available information on long term trends in OHV use and present it as case studies.

Although monitoring of OHV trails is not standardized and is generally unorganized, some areas do have information that could be used to evaluate long-term trends. For example, more than 20 years ago, the Angeles National Forest had trails at Rowher Flat measured on aerial photographs; remeasurements could be made on recent aerial photos to evaluate the changes that have occurred since the Forest has gone from unrestricted OHV use to a managed program. Another example is the Mendocino National Forest, which has photo records documenting changes in the trail system as trails on old firelines have been rehabilitated and replaced. There may be other special situations where baseline data has already been collected. We recommend these situations be analyzed for long-term trends and presented as case studies.

8. More recognition is needed for effective OHV programs, and Districts with deficiencies should be held accountable.

Forests and Districts with good OHV programs deserve more recognition for the good job they are doing. This would also give more visibility to programs and practices that are effective. Those Districts with deficiencies should be held accountable, but more importantly, identified as needing more technical assistance and support.

9. The Region should explore ways to fund OHV programs at a base level.

Ranger Districts and Forests cannot build and maintain a stable OHV program that retains experienced operators when funding from the State is unpredictable from year to year. This current season, the delays in funding caused several Districts to lose an entire season of maintenance because they had no funds to operate when soil moisture was suitable. In past years,

some Districts were able to keep up with maintenance only because high fire hazards forced trail closures.

The Regional Office and the State should work together to develop a method of funding essential annual maintenance, training, and OHV program administration that is stable from year to year. Major projects, new equipment, and special needs could continue to be funded by grant proposals.

Authors

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Roger Poff has more than 40 years experience in soil and watershed management, including eight years as a private consultant. He is a Certified Professional Soil Scientist, a Certified Erosion and Sediment Control Specialist, and a Registered Professional Forester. Mr. Poff has extensive experience in soil and water quality monitoring and watershed management. For the past six years he has been the prime contractor for CDF's hillslope monitoring program and has evaluated erosion and sedimentation on 275 timber harvest plans throughout California. As a consultant, Mr. Poff developed and monitored BMPs for the Hayfield Draw/Bryant Park OHV area on the Prescott National Forest in Arizona. He also made major contributions to the soil and watershed sections of the Rock Creek Recreational Trail Area EIS on the Eldorado National Forest.

Mr. Poff has worked as a soil scientist in Minnesota, South Dakota, Montana, and—for the last 20 years—California. While with the US Forest Service he served as Soil, Watershed and Geology Staff Officer on the Beaverhead National Forest; Acting Watershed, Range and Wildlife Staff Officer on the Tahoe National Forest; and Zone Soil Scientist for National Forests in the northern Sierra Nevada.

Thomas M. Ryan

Tom Ryan has more than 42 years experience as a soil scientist. He is a Certified Erosion and Sediment Control Specialist. Mr. Ryan has extensive experience in developing land use and soil suitability ratings and has developed monitoring techniques for measuring soil impacts related to a variety of land management activities. From 1980 to 1995 he was Zone Soil Scientist for the four National Forests in southern California, where he developed soil interpretations and monitoring procedures for OHV. Mr. Ryan was a member of the soil loss standards committee that developed soil conservation guidelines for OHV recreation management in California.

Prior to his assignment as Zone Soil Scientist, Mr. Ryan was a Forest Service soil scientist on the Plumas, Umpqua, and Angeles National Forests. He was also a soil scientist with the Soil Conservation Service, and for four years was a land classification specialist with the University of Hawaii. For six years, Mr. Ryan was a soils laboratory technician at the University of California—Riverside.

Appendix 1 – Photos

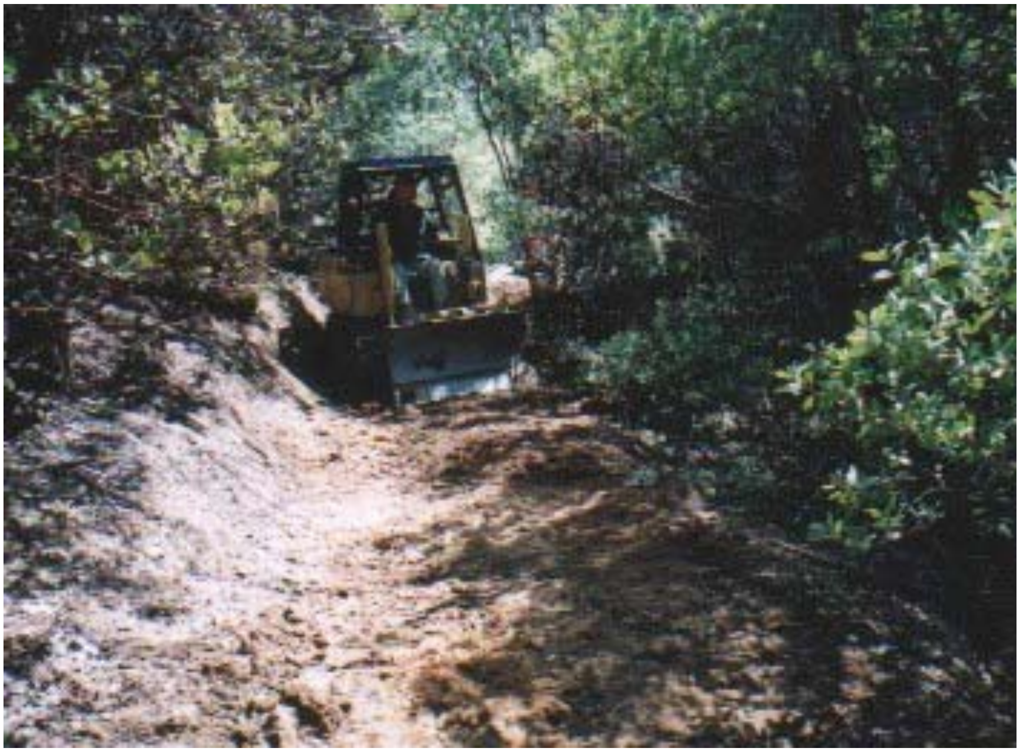

Photo 1. SWECO 480 backblading berm. Note wider appearance of trail.
Sled Ridge Trail, Upper Lake RD, Mendocino NF, 4/11/01.

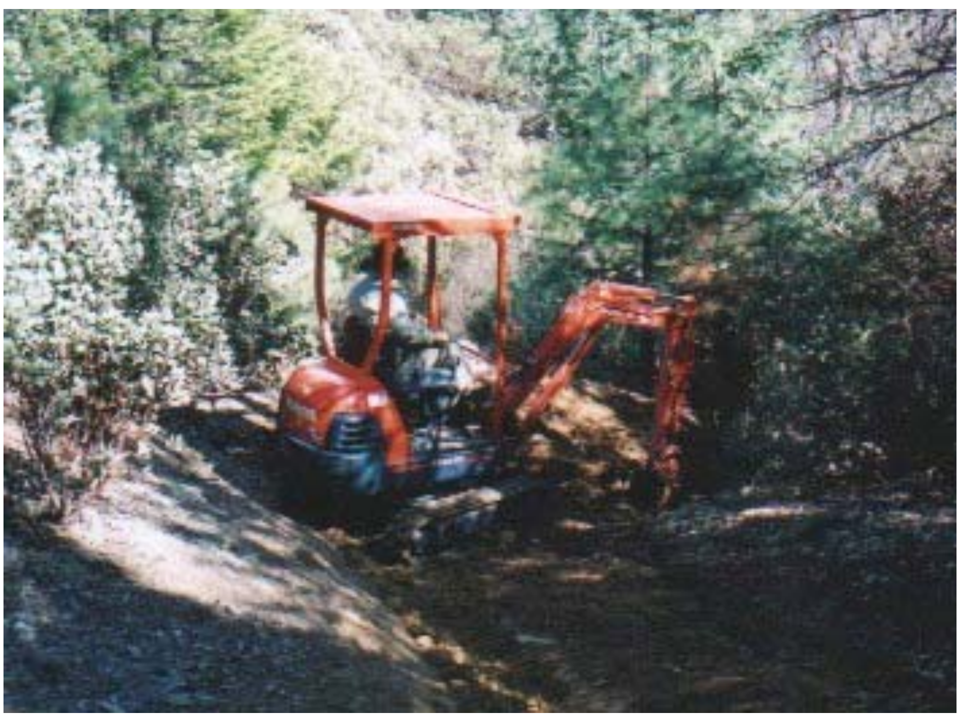

Photo 2. Kubota excavator (16-in bucket) cleaning out sediment trap.
Sled Ridge Trail, Upper Lake RD, Mendocino NF, 4/11/01.

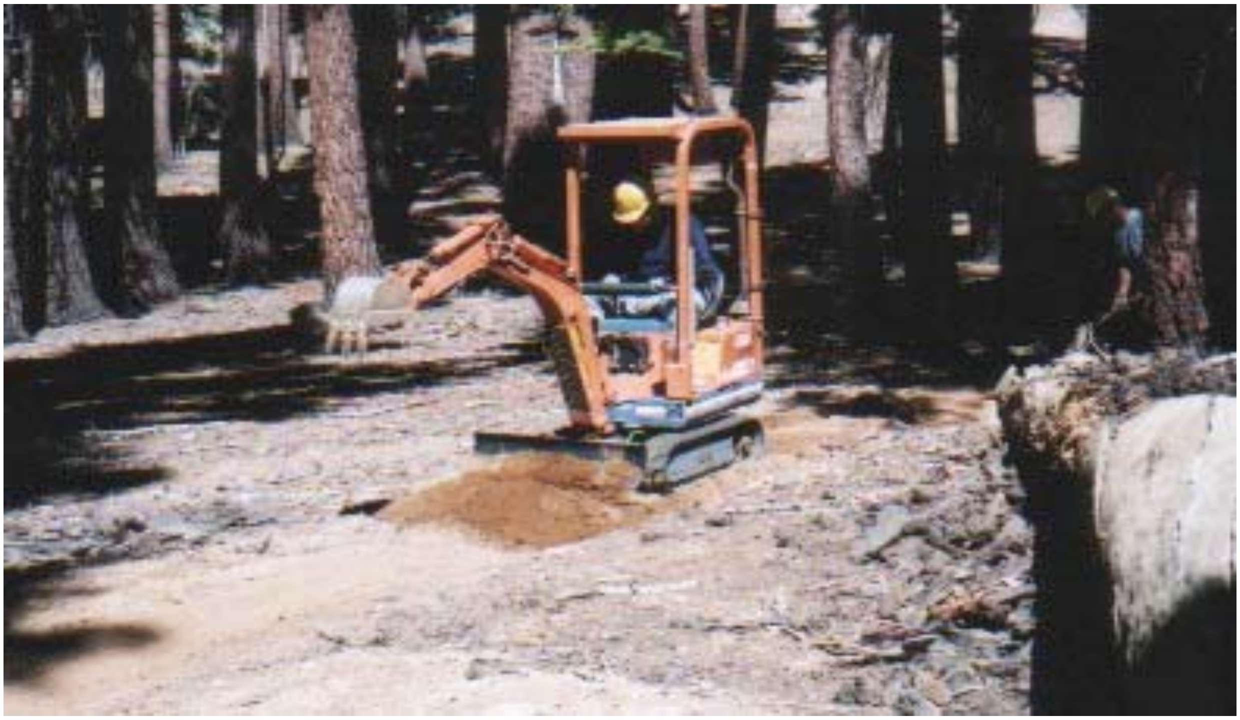

Photo 3. Kubota excavator (8-in bucket) blading trail. Cannell Meadows RD, Sequoia NF, 6/1/01.

Photo 4. Trail bladed with Kubota mini-excavator. Cannell Meadows RD, Sequoia NF, 6/1/01.

Photo 5. SWECO 450 constructing OHV rolling dip on old road.
Georgetown RD, Eldorado NF, 4/30/01.

Photo 6. Single-track trail maintained with Pacific Crawler 240DL.
Grindstone RD, Mendocino NF, 4/25/01

Photo 7. Single-track trail constructed and maintained with SWECO 450.
Santa Clara-Mojave Rivers RD, Angeles NF, 5/3/01

Photo 8. Single-track trail constructed with SWECO trail tractor.
Downieville RD, Tahoe NF, 6/13/01.

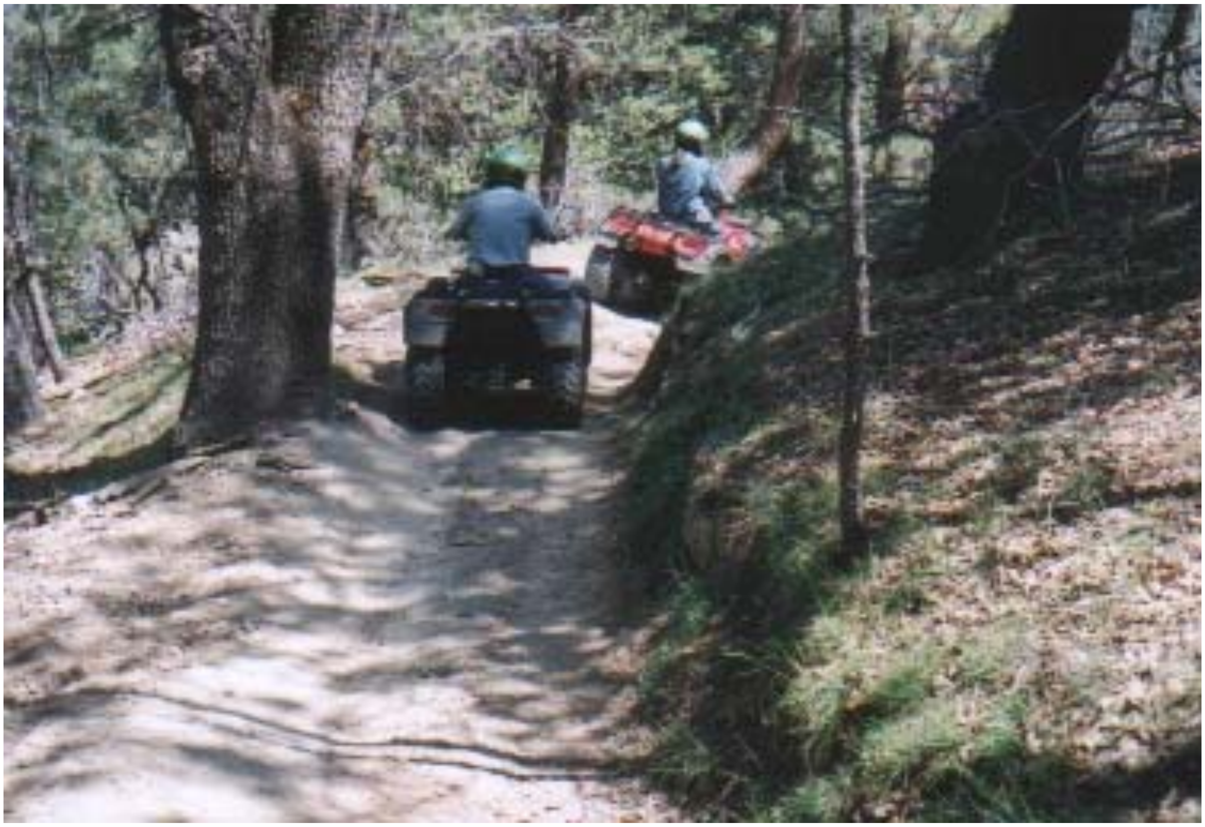

Photo 9. ATVs on multi-use trail maintained with SWECO trail tractor. Note wider tread. Mountain Top RD, San Bernardino NF, 5/1/01.

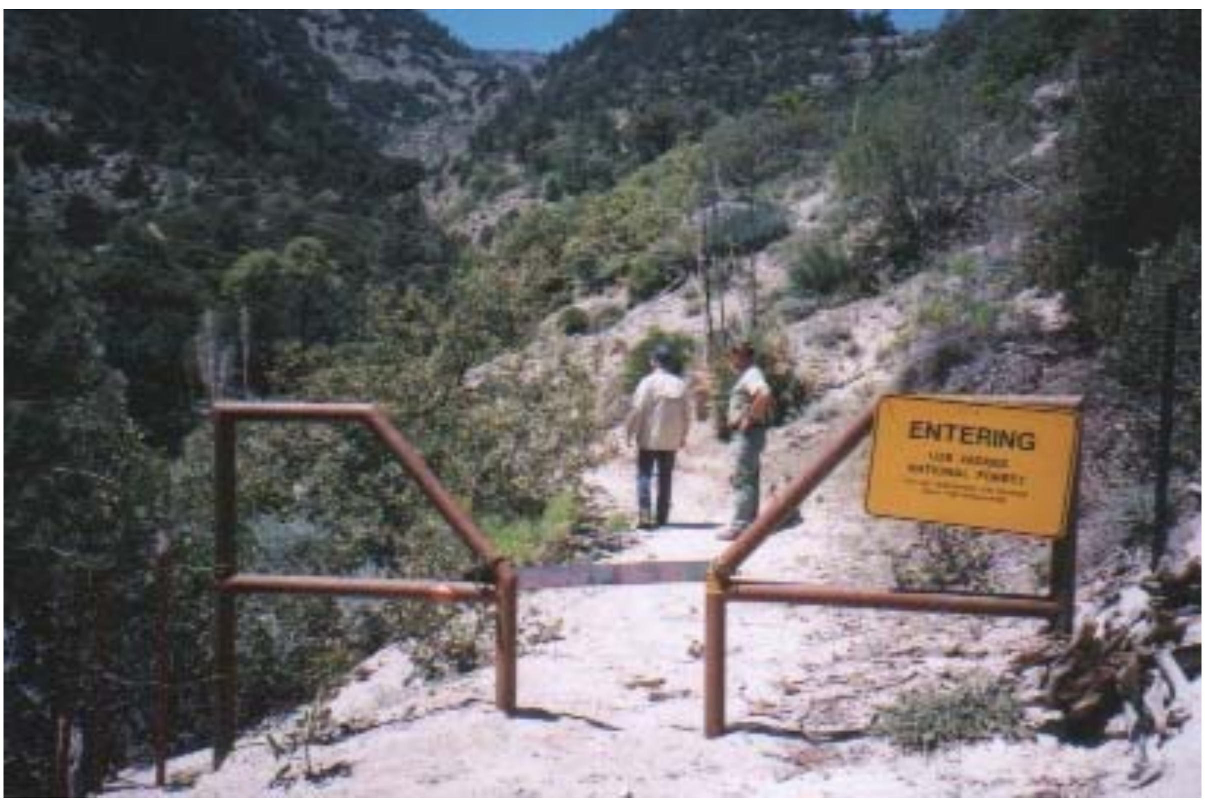

Photo 10. Trail barrier to exclude ATVs. Mt. Pinos RD, Los Padres NF, 5/2/01.

APPENDIX 2 - Trail segments Visited in the field

Sled Ridge Trail	Upper Lake RD, Mendocino NF
Trail 22, Trough Springs Ridge	Grindstone RD, Mendocino NF
Trail 3, Trough Springs Ridge	Grindstone RD, Mendocino NF
New construction	Georgetown RD, Eldorado NF
Old road section	Georgetown RD, Eldorado NF
Sly Park trail	Placerville RD, Eldorado NF
N. Shore Admin Trail 3W12	Mtn. Top RD, San Bernardino NF
Trail 3N34	Mtn. Top RD, San Bernardino NF
Trail 3W14	Mtn. Top RD, San Bernardino NF
Trail 3W11	Mtn. Top RD, San Bernardino NF
Lockwood Canyon 4WD Trail	Mt. Pinos RD, Los Padres NF
East Frazier Trail	Mt. Pinos RD, Los Padres NF
Gold Hill Trail	Mt. Pinos RD, Los Padres NF
South Portal Trail	Santa Clara-Mojave Rivers RD, Angeles NF
Sugar Pine Staging Area	Foresthill RD, Tahoe NF
Trail Loop 7	Foresthill RD, Tahoe NF
Rincon Trail	Cannell Meadows RD, Sequoia NF
Sherman Pass Trail	Cannell Meadows RD, Sequoia NF
Jackass Trail	Cannell Meadows RD, Sequoia NF
First Divide Trail	Downieville RD, Tahoe NF
Second Divide Trail, 1133E	Downieville RD, Tahoe NF
Deer Creek Trail	Mi Wuk RD, Stanislaus NF
Summit 4WD Trail	Summit RD, Stanislaus NF

APPENDIX 3 - REVIEW PARTICIPANTS

Equipment Operators and OHV Managers Interviewed

Jeff Applegate	Grindstone RD, Mendocino NF
Steve Bailey	Summit RD, Stanislaus NF
Joel Baucher	Sierra City (Contractor)
Mike Burmann	Georgetown RD, Eldorado NF
Dale Denneweth	Arrowhead RD, San Bernardino NF
Bob Frenes	Cannell Meadows RD, Sequoia NF
Keith Ginn	Mt. Pinos RD, Los Padres NF
Bill Haire	Downieville RD, Tahoe NF
Tom Kaucher	Santa Clara-Mojave Rivers RD, Angeles NF
Mark Lambert	Foresthill RD, Tahoe NF
Cam Lockwood	Trails Unlimited, R-5
Mike Mendoza	Cannell Meadows RD, Sequoia NF
Charlie Morgan	Volunteer, Grindstone RD, Mendocino NF
Chris Obey	Mi Wuk RD, Stanislaus NF
Kurt Sattler	Foresthill RD, Tahoe NF
Bill Walker	Supervisor's Office, Eldorado NF
Sky Zaffarano	Upper Lake RD, Mendocino NF

Concerned Citizens Who Provided Comments by Letter or E-mail

Karen Schambach

Tom Walsh

Howard Wilshire

Dave Wood

Concerned Riders Who Participated in Field Interviews

Don Amador	Blue Ribbon Coalition
Bill Dart	American Motorcyclist Association
Dave Wood	Chicago Park, CA

APPENDIX 4 - EQUIPMENT OBSERVED

SWECO 480	Upper Lake RD, Mendocino NF
Kubota Excavator, 16-inch bucket	Upper Lake RD, Mendocino NF
ATV with Rock Rake	Upper Lake RD, Mendocino NF
Pacific Crawler 240 DL	Grindstone RD, Mendocino NF
SWECO 450	Georgetown RD, Eldorado NF
SWECO 450	Arrowhead RD, San Bernardino NF
AccuTrac	Arrowhead RD, San Bernardino NF
Bobcat Excavator, 12-inch bucket	Mt. Pinos RD, Los Padres NF
SWECO 450	Mt. Pinos RD, Los Padres NF
SWECO 450	Foresthill RD, Tahoe NF
ATV with Harrow	Foresthill RD, Tahoe NF
Takeuchi Excavator, 18-inch bucket	Foresthill RD, Tahoe NF
Kubota Excavator, 8-inch bucket	Cannell Meadows RD, Sequoia NF
SWECO 450	Summit RD, Stanislaus NF

APPENDIX 5 - MONITORING PLAN

1. COMPLIANCE MONITORING

Compliance monitoring should be completed annually on each District that has done maintenance or construction with mechanized equipment. This monitoring could be conducted by staff at the Supervisor's Office or on the District.

(1) Obtain a map that shows trails maintained or constructed with mechanized equipment.

(2) Compare each completed Standard and Guideline (S&G) checklist form (Appendix 6) with the map to verify that a form was completed on all trails maintained or constructed with mechanized equipment.

(3) Check each form to verify that it was properly completed.

(4) Prepare a brief summary of the results of this monitoring.

(5) Share the results of the monitoring with the equipment operators and discuss the need for improvements in the forms or how they are being used.

(6) Forward the monitoring summary to the Regional OHV Coordinator.

2. IMPLEMENTATION AND EFFECTIVENESS MONITORING

This monitoring should be conducted annually on all trails that have been maintained or constructed using mechanized equipment. The sampling protocol described below is designed to evaluate the S&Gs as they are applied on each District. The sample pool in this case is all qualifying trails on the District. See the discussion below for other alternatives to defining sample pools.

Sampling Procedure

The sample unit to be monitored is a waterbreak plus the trail segment upslope to the next waterbreak. One implementation and effectiveness form (Appendix 7) is to be completed on each sample unit selected.

(1) Obtain a map showing all trails maintained or constructed with mechanized equipment.

(2) Divide the total length of qualifying trails into approximately 500-foot segments and number each consecutively. The 500-foot segments need not be measured precisely. To put this in perspective, for 18 miles of trail this process would identify approximately 190 500-foot segments.

(3) Note the total number of segments numbered, and randomly select **four** for sampling, using a random number table or the random number function on a scientific calculator.

(4) In the field, ride or walk until you are within one of the randomly selected 500-foot trail segments, and flip a coin to determine the direction of travel to the first sample unit (heads=forward, tails=back). This will also be the direction of travel for sampling subsequent sample units.

(5) Walk in this direction to the first waterbreak. This could be a reverse grade rolling dip, an OHV rolling dip, or a natural low point in the trail—wherever water was intentionally drained off the trail. This waterbreak, and the segment of trail it drains, is the first sample unit to monitor.

(6) Flag the waterbreak, and note its location on a map or obtain a UTM location using G.P.S.

(7) Walk the trail upslope to the next waterbreak, observing whether the S&Gs were implemented and how effective they were in maintaining trail tread and minimizing sedimentation. Return to the waterbreak and evaluate it also. Note these observations on the monitoring form shown in Appendix 7. Take photos of the trail segment and waterbreak.

(8) Flip a coin to determine the next waterbreak/trail segment to sample. Heads = 2nd, tails = 3rd waterbreak along the trail in the direction determined under (4).

(9) Continue sampling until **three** waterbreak/trail segment sample units have been observed. This completes the sampling at the first of the four randomly selected 500-foot trail segments.

(10) Repeat steps (4) through (9) until monitoring has been completed on all four randomly selected trail segments.

When monitoring each sample set, if a trail junction is reached before the required three samples have been located and observed, follow the trail that has been maintained with mechanical equipment. If both qualify for sampling, flip a coin to determine which trail fork to take (heads = right, tails = left). If the end of the qualifying trail is reached before three samples have been observed, return to the first waterbreak sampled and continue sampling in the opposite direction.

This procedure will yield 12 randomly sampled waterbreaks on each District. Our past experience with this type of monitoring suggests this is the minimum level of sampling needed to get meaningful results. In any case, the process should be field-tested before full scale implementation.

Data Collection

The field form shown in Appendix 7 is set up to evaluate S&G. The implementation part (list of the S&Gs) can be modified as needed, by adding or deleting S&Gs, without affecting the effectiveness part. In the effectiveness part, the ten basic observations assess erosion and sedimentation on trails as they relate to the basic concerns raised about the use of mechanical equipment to maintain and construct OHV trails—trail widening, tread loss, and sediment delivery.

General Discussion

Once familiar with the process, an experienced professional should require no more than 10 to 15 minutes in the field to fill out a field data sheet and take a photo on each sampling unit. The largest time component in this type of monitoring is physically getting to the sample site.

Although the sampling is random and the data collected can be quantified, the basic field observations are qualitative and do require professional judgment. Monitors should be familiar with how OHVs affect tread wear and how trail tractors are used to maintain trails. We recommend the monitoring be done by professionals in erosion and sediment control or by resource technicians trained by them.

If the monitoring is done by an individual, or by a very small group of trained professionals, the data set will be repeatable and consistent. In this case, a relatively small data set would be sufficient to draw valid conclusions. If the monitoring is done by a larger group of resource technicians—even if trained by professionals—field observations will be more variable and a much larger data set will be needed to draw conclusions. This approach would also require some quality control. In the end, the cost of these two approaches may not differ significantly. The second approach has the advantage of getting more people involved in the process, which may help meet other OHV management objectives.

In the sampling protocol described above, each District is an individual sample pool. While this would provide good information on individual Districts (and operators), it would not necessarily represent how well the S&Gs are being implemented on a Regional basis. If this Regional view is of greater interest, the sample pool from which sample units are drawn should be all trails in the Region that qualify.

The important point is this: the questions the monitoring will be expected to answer should be carefully formulated before the sample pool is defined.

APPENDIX 6 - STANDARD AND GUIDELINE FIELD CHECKLIST FORM

Forest _________________ District _________________ Trail Seg _____________

Operator _____________________ Assistant(s) _______________Date _________

Activity: maintenance reconstruction new construction

Equipment: SWECO 480/450 Mini-excavator (size) _____ Other _________

Drainage: outslope OHV Rolling Dip Rev Grade RD Other

Last Maintenance (mo/yr) ______ Maintenance Objective _____________________

____

Standard & Guideline	Yes	No	N/A
1. This Standard and Guideline checklist was reviewed before starting maintenance or construction on this trail			
2. Equipment was operated by certified operators, or under their direct supervision			
3. If new, this trail was constructed to R-5 design standards			
4. If new, this trail has been closed to all use for one season			
5. OHV rolling dips were constructed/maintained by compacting moist soil in small lifts			
6. Before equipment was moved in, this trail was examined to determine the need for maintenance with mechanical equipment			
7. The blade was lifted and the equipment walked across sections of trail that needed no maintenance			
8. Drainage structures, and the tread between them, were examined for evidence of tread loss before starting maintenance			
9. At failed drainage structures, the cause of failure was determined before starting repairs			
10. Soil collected in rolling dip outlets was recycled into rolling dip structures or back onto the trail tread			
11. Outside berms were worked back into the trail tread,			

Standard & Guideline	Yes	No	N/A
not bladed off the trail as sidecast			
12. Rills and gullies in treads were repaired with soil reclaimed from rolling dip outlets or from outside berms, not by blading the trail tread			
13. Soil sloughed from cutbanks or sideslopes above the trail was bladed only as needed to maintain a safe trail; cutbanks were not bladed into or undercut			
14. “Stutterbumps” were repaired by ripping, blading, and compacting trail treads when soil was moist (except for non-cohesive soils)			
15. The amount of soil moved was the smallest amount needed to meet the maintenance objective			
16. Where soil was too dry for compaction, maintenance on drainage structures was deferred or done by hand			

Comments

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Instructions

Review this form for each OHV trail constructed or maintained with mechanical equipment. Complete one form for each day equipment is operated, or for a trail loop or other trail segment if a variety of trail types are done in the same day.
Fill in Forest, District, name of operator and assistants, and date. Note the starting and end point of the trail section the form covers. Circle the activity type, and equipment type. Note size of bucket on mini-excavator. Circle all drainage types that apply. If known, enter month/year of last maintenance by mechanical equipment, or if not known, estimate years since last maintenance and note “est.” Write out the maintenance objective for the trail section, including any special needs or concerns related to drainage, sedimentation, or tread wear.

For each S&G enter a checkmark in the Yes, No, or N/A (does not apply) columns. If “no” is checked, enter a footnote number and write a brief explanation under comments.

Appendix 7, Page 1 Monitoring Field Form
Implementation and Effectiveness Monitoring

Forest _______________ District _____________ Trail _____________ UTM ____________________

Sample Length ________ ft Bearing _________ Trail Gradient ____ % Sideslope Gradient ____ %

Vegetation Type _______________________ Bedrock ______________ Photo No. ______________

Trail Drainage: outslope flat confined Drainage Structure: OHV RD Rev Grade RD Other

Soil Type: clayey loamy sandy Rock Fragments (%): <15 15-50 >50 Soil Depth shallow deep

Observers ____ Date ________________

Notes ____

Standard and Guideline	Problem Point	Implementation	Effectiveness
This Standard and Guideline checklist was reviewed before starting maintenance or construction on this trail			
Equipment was operated by certified operators, or under their direct supervision			
If new, this trail was constructed to R-5 design standards			
If new, this trail has been closed to all use for one season			
The blade was lifted and the equipment walked across sections of trail that needed no maintenance			
Soil collected in rolling dip outlets was recycled into rolling dip structures or back onto the trail tread			
Outside berms were worked back into the trail tread, not bladed off the trail as sidecast			
Soil sloughed from cutbanks or sideslopes above the trail was bladed only as needed to maintain a safe trail; cutbanks were not bladed into or undercut			
The amount of soil moved was the smallest amount needed to meet the maintenance objective			
Where soil was too dry for compaction, maintenance on drainage structures was deferred or done by hand			

Instructions The sample unit is a waterbreak plus the trail segment upslope to the next waterbreak. Walk the trail segment and examine the waterbreak. Complete the back side (effectiveness) of this form to identify problem points. Enter problem point numbers in first column for all S&Gs each applies to. Then rate implementation and effectiveness as follows:

Implementation

A = Acceptable
S&G fully implemented

MA = Marginally Acceptable
S&G partially implemented

D = Departure
S&G not implemented

Effectiveness

E = Effective
No observable loss of tread; no sediment delivery to RMZ

ME = Marginally Effective
Tread loss barely observable; sediment delivered to RMZ

I = Ineffective
Clearly observable tread loss; sediment delivered to high flow of stream channel

Appendix 7, Page 2   Monitoring Field Form - Effectiveness Monitoring

1. Tread Wear
   - ☐ No rills or gullies on tread; tread shows only minor soil loss
   - ☐ Rills occur on lower 1/3 of trail segment only
   - ☐ Gullies are present, or rills extend into upper 2/3 of trail segment

2. Cutslope Erosion
   - ☐ no material has been bladed from cutslope side of trail
   - ☐ soil sloughed from cutslope, or eroded from sideslope above trail, has been bladed off and worked into tread, but cutbank has not been bladed into
   - ☐ cutbank was bladed into, or sloughed material was bladed off as sidecast

3. Outside Berm
   - ☐ outside berm was not bladed, or berm was bladed in and reworked into tread
   - ☐ outside berm was bladed in and reworked into tread, and less than 25% of fillslope has berm material sidecast onto it
   - ☐ the berm has been bladed off onto the fillslope, or more than 25% of fillslope has berm material sidecast onto it

4. Fillslopes
   - ☐ no rills or gullies on fillslopes
   - ☐ rills occur on <15% of fillslope, and rills do not extent beyond the toe of the fillslope
   - ☐ rills or gullies occur on >15% of fillslope, or rills extend beyond toe of fillslope

5. Water Diversion
   - ☐ all runoff from the tread is diverted by the waterbreak
   - ☐ <15% of runoff from the tread bypasses the waterbreak
   - ☐ >15% of runoff passes over, through, or around the waterbreak

6. Waterbreak Wear
   - ☐ traffic wear is slight and drainage function is not threatened
   - ☐ traffic wear is moderate and drainage function is threatened
   - ☐ traffic wear is heavy; structure is unlikely to last until next maintenance

7. Transition Wear
   - ☐ transition wear is slight
   - ☐ wear on transition is moderate, but structure is not threatened
   - ☐ heavy wear on transition that will contribute to eventual structure failure

8. Effectiveness of Sediment Capture at Waterbreak Outlet
   - ☐ all sediment is trapped, and trap has sufficient capacity for runoff
   - ☐ nearly all sediment is trapped, and trap has capacity for almost all runoff
   - ☐ sediment is not being trapped at waterbreak outlet

9. Reclamation of Trapped Sediment
   - ☐ all trapped sediment can be recycled into tread or structure
   - ☐ 75% of trapped sediment can be recycled into tread or structure
   - ☐ trapped sediment cannot be recycled on to waterbreak structure or tread

10. Sediment Delivery from Waterbreak Outlet or Trail
    - ☐ all sediment is trapped or filtered out before reaching a RMZ
    - ☐ some sediment has reached a RMZ or a Class IV watercourse
    - ☐ some sediment reaches the high water channel of a Class III or larger watercourse

APPENDIX 8 – FIELD MOISTURE DETERMINATION

In order to have enough strength to resist the wear of OHV traffic, trail treads and drainage structures must be compacted. The degree of compaction that can be achieved during construction and maintenance is a function of soil moisture content. This Appendix explains how soil moisture affects the compaction process, and describes some simple field observations that can be used to determine when soils are sufficiently moist for maintenance and construction operations with mechanized equipment.

Basic Principles of Soil Compaction

Soil compaction is a process whereby soil strength and density are increased by reducing soil pore space; this is essentially squeezing the air out of the soil. Soil is most easily compacted when soils are moist and pores are only partially filled with water. Under these conditions the fine pores contain enough water to reduce internal friction, but the coarse pores are empty and compressible. When a load is applied, soil particles are rearranged and packed tightly. This increases soil density and soil strength, and allows the compacted soil to resist the wear of traffic.

When soils are wet, or nearly saturated, soil strength is very low. Compaction does not occur under these conditions because nearly all soil pores are filled with water and water is not readily compressed. When a load is applied to saturated soils a form of displacement called puddling occurs. This is similar to squeezing toothpaste from a tube. Puddling destroys soil structure, and although puddled soils may increase in density as they dry out, puddled soils do not have the strength of compacted soils.

When soils are dry, soil strength is high. Dry soils are difficult to compact because particle bonding is strong and there is insufficient moisture to lubricate soil particles and facilitate packing. Mechanical disturbance of dry soils increases soil porosity by shattering compacted layers. Once shattered, dry soils cannot be recompacted, and additional disturbance merely displaces the soil.

Field tests For Soil Moisture

To determine whether soils are moist enough for compaction, simply take a handful of soil and squeeze it, trying to mold it into a ball. If squeezing reduces the volume of soil, and a ball can be formed that holds together when handled, the soil is sufficiently moist to compact. If the volume of soil cannot be reduced, and a ball cannot be formed, or if the soil separates when pressure is released, the soil is too dry to compact. If water or wet soil oozes from between the fingers when the soil is squeezed, the soil is too wet to compact.

The moisture content at which compaction will occur varies by soil type. Soil particle size distribution, or soil texture, affects both the moisture content and the range of moisture content within which compaction will occur. Where the clay content is high, compaction occurs over a wide range of soil moisture; where the clay content is low, compaction occurs within a narrow range of soil moisture. Table 1 describes by soil texture groups some indicators of soil moisture levels at which compaction will occur.

Sampling

When determining whether a trail segment has sufficient moisture for construction or maintenance activities, soil moisture should be examined at several locations and depths. Under field conditions, soil moisture varies by soil type, with depth, from place to place along a trail, and even from place to place within a single drainage structure. Aspect, elevation, vegetative type, shading, and surface drainage all affect soil moisture content.

Adding Water

Soils thoroughly moistened by rainfall or snowmelt generally provide the best conditions for trail maintenance. However, situations may occur where maintenance is needed, but where soils are too dry to compact. If water is available, the soil may be artificially moistened to facilitate compaction. However, it is very important to bring all the soil that will be moved up to the proper moisture content before grading and compaction. Moist soil should be added to drainage structures in small lifts before compacting it. Wetting down structures that have already been constructed with dry soil will not result in compaction or an increase in soil strength.

Monitoring

Observing how equipment interacts with the soil can indicate how well the soil is being compacted. Equipment tracks without berms indicate compaction is taking place; berms of soil along tracks indicate displacement.

The effectiveness of soil compaction can be tested in the field with a simple T-handle probe constructed of 3/8-inch rebar. The force needed to push the probe into the soil is an indicator of soil strength. Comparing the resistance to penetration between a compacted drainage structure and a nearby undisturbed, compacted trail tread can indicate how effectively the structure has been compacted.

Appendix 8, Table 1 Field indicators of soil moisture contents suitable for compaction, by soil texture groups

Soil Moisture Content	Coarse Soils*	Light Soils	Medium Soils <35% clay	Heavy Soils >35% clay
	Sands, Loamy Sands, and Very Coarse Sandy Loams	*Coarse, Medium, and Fine Sandy Loams*	*VF Sandy loam, Loam, Silt Loam, Sandy Clay Loam, Light Clay Loam*	*Heavy Clay Loam, Silty Clay Loam, Sandy Clay, Clay*
Dry	loose, single grained; flows through fingers	loose; flows through fingers	powdery; sometimes slightly crusted but breaks down into powder	hard, baked, cracked; sometimes has loose crumbs on surface
Slightly Moist	still appears dry; will not form a ball with pressure	still appears dry; will not form a ball with pressure	somewhat crumbly, but ball holds together after release	somewhat pliable; forms a ball under pressure
Moist	still appears dry, will not form a ball with pressure	tends to form ball with pressure, but ball seldom holds together	forms a ball and is very pliable; slicks readily if high in clay	easily ribbons out between fingers; has a slick feeling
Very Moist	tends to stick together slightly; sometimes forms a very weak ball	forms a weak ball with pressure; ball breaks easily; will not slick	forms a ball and is very pliable; slicks readily if high in clay	easily ribbons out between fingers; has a slick feeling
Wet	free water may appear on squeezing; wet outline is left on hand	free water may appear on squeezing; wet outline is left on hand	can squeeze out free water; wet outline is left on hand	puddles and free water forms on surface; wet outline is left on hand

(dark grey)	moisture level suitable for compaction
(light grey)	moisture level marginally suitable for compaction
(white)	soil too dry or too wet for compaction

* Coarse soils cannot be compacted by force when moist; compaction requires vibration